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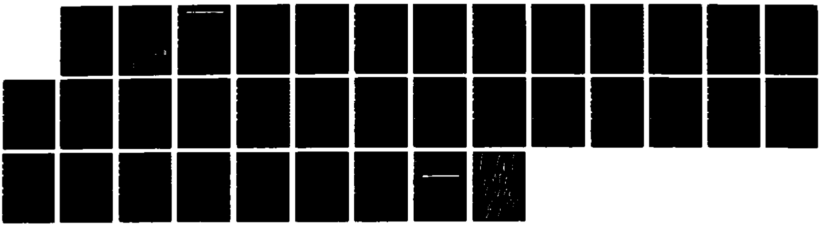

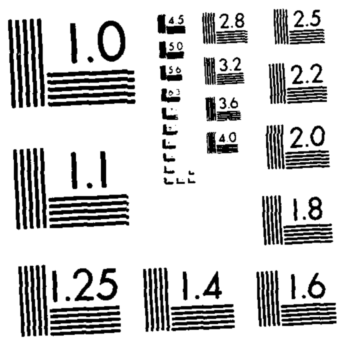
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David W. Taylor Naval Ship Research and Development Center

Bethesda, MD 20084-5000

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Ship Hydromechanics Department

Research and Development Report

LABRADOR SEA WAVE AND ICE MEASUREMENTS IN SUPPORT OF THE MARCH 1987 LABRADOR SEA ICE MARGIN EXPERIMENT (LIMEX)

by

William L. Thomas III

DTRC/SHD-1212-05 Labrador Sea Wave and Ice Measurements in Support of the March 1987 Labrador Sea Ice Margin Experiment (LIMEX)

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ABSTRACT

The Labrador Ice Margin Experiment 1987 (LIMEX '87) was conducted aboard CSS BAFFIN from 15 March to 27 March 1987 in the southern Labrador Sea, off the east coast of Newfoundland. Five wave measurements were made in the vicinity of the ice edge using Delft disposable wave buoys. Wave measurements were compared with Global Spectral Ocean Wave Model (GSOWM) forecasts which were provided by the Fleet Numerical Oceanography Center in Monterey, California. Ice edge observations were compared with ice edge forecasts provided by the Naval Polar Oceanography Center in Suitland, Maryland. Observations regarding ship operations in ice regions are also discussed.

ADMINISTRATIVE INFORMATION

The work reported herein was sponsored by Code 1331 of the Naval Research Laboratory (NRL) under Program Element 63207N of Research Project X0527. It is identified by Work Unit Number 1-1561-129 at the David Taylor Research Center (DTRC).

INTRODUCTION

Knowledge of prevailing wave environments is an essential factor in improving the seakeeping performance of ships. Open ocean wave measurements and forecasts, which are available from several sources, have only recently been considered during the ship design process.[1] Recent interest of the U.S. Navy in northern latitude operations has identified several hazards to ships operating in cold weather regions. Two of these hazards are heavy sea states and floating ice.[2] If the ship design process is to improve the capability of ships operating in the vicinity of floating ice, environmental wave data in the Marginal Ice Zone (MIZ) must be gathered to allow accurate predictions of seakeeping performance.

The March 1987 deployment of the CSS BAFFIN to the Labrador Sea to conduct the Labrador Sea Ice Margin Experiment (LIMEX '87) provided the opportunity to measure ocean waves in the vicinity of the ice edge. Ice edge observations were taken for comparison with ice edge forecast products. Observations relating to ship handling

in ice regions were also recorded. The objective of this report is to compare in situ measurements with prediction products.

WAVE MEASUREMENTS

STATEMENT OF THE PROBLEM

Forecasts of directional wave spectra are available to Navy ships from the Fleet Numerical Oceanography Center (FNOC) in Monterey, California through use of the Global Spectral Ocean Wave Model (GSOWM). Forecasts are provided to ships in message format at times 0000Z and 1200Z daily for global locations which are spaced every 2.5 degrees latitude and longitude. Although GSOWM is somewhere between a first and second generation wave model, it has yet to be fully validated. Therefore, the need exists to make an operational comparison of measured wave and GSOWM forecasts in northern latitudes.

APPROACH

A wave measurement trial was conducted aboard CSS BAFFIN during LIMEX '87. This sea trial took place in the Labrador Sea from 15 March to 27 March 1987. Wave height measurements were conducted along the ship's route using the Delft disposable wave buoy. In all cases the buoy was recovered. All wave buoy measurements were made within 3000 meters of a well-defined ice edge.

INSTRUMENTATION

The primary instrumentation for the wave measurements were two disposable wave buoys which were developed by the Ship Hydromechanics Laboratory of the Delft University of Technology, in Delft, The Netherlands (see Fig. 1 from Reference 3). The Delft disposable buoy differs from other wave buoys in that it is sufficiently small to allow deployment by one person without crane assistance. Thus, it is easy to deploy with minimum impact to ship operations. The ease of handling and low

cost design constraints of the buoy have permitted only a capability for vertical acceleration measurement. Thus, only a point spectrum can be derived from the data with no determination of directional characteristics. Significant characteristics of the Delft buoy are listed in Table 1. Delft buoys are constructed of fiberglass and steel. The buoy's sphere contains a battery pack, fixed vertical accelerometer, transmitter, and electronics package.[4] The Delft disposable buoy transmitted continuous data of vertical acceleration which were recorded on analog tape by instrumentation aboard CSS BAFFIN.

Buoy measurement locations are displayed in Fig. 2 with a corresponding summary of buoy deployments listed in Table 2.

DATA ANALYSIS

Analog time history data of Delft wave buoy acceleration measurements were digitized and double integrated using routines developed by Code 1561 of DTRC. Analysis routines utilize Fast Fourier Transform processing to calculate spectral densities. Calculated buoy spectra are shown in Figs. 3 through 7.

Ninety-five percent confidence bands for the wave buoy measurements were calculated utilizing Reference 5 statistical techniques which apply to Fast Fourier Transform processing. Briefly stated, for spectral density calculations:

$$\frac{vS(f)}{\chi_v^{2}(100-\alpha)/2} \le S'(f) < \frac{vS(f)}{\chi_v^{2}(100+\alpha)/2}$$

where

$S'(f)$ = true value of spectral density

$S(f)$ = calculated spectral density

v = degrees of freedom

χ^2 = chi-square value

α = percent confidence level

For significant wave height measurements:

$$\left(\frac{v}{\chi_v^{2}(100-\alpha)/2}\right)^{1/2} (\tilde{\zeta}_w)_{1/3} \leq (\tilde{\zeta}_w')_{1/3} < \left(\frac{v}{\chi_v^{2}(100+\alpha)/2}\right)^{1/2} (\tilde{\zeta}_w')_{1/3}$$

where

$(\tilde{\zeta}_w')_{1/3}$ = true value of significant wave height

$(\tilde{\zeta}_w)_{1/3}$ = calculated significant wave height

v = degree of freedom

χ^2 = chi-square value

α = percent confidence level

DISCUSSION

Delft wave measurement number 01 (Fig. 3) was taken in the vicinity of First Year broken ice having a concentration of 8/10. Ice thickness measurements taken in this area on 19 March by survey teams varied between 0.3 and 2.5 meters. Southeasterly winds during the previous two and one half days compacted the ice creating a well-defined ice edge which ran from southwest to northeast. The Delft wave buoy was deployed in an open lead approximately 500 meters inside the ice edge. The measured spectra (Fig. 3) indicates a swell dominant seaway with a peak at 0.125 Hz. This measurement was in excellent agreement with visual observations taken during the buoy deployment.

Delft wave measurement number 02 (Fig. 4) was taken in the vicinity of First Year broken ice having a concentration of 10/10. Measured ice thicknesses taken in this area varied between 0.3 and 2.5 meters. Northeasterly winds began on 20 March due to the influence of a low pressure system located approximately 420 nautical miles to the southeast of the buoy deployment position. These winds continued to apply pressure to the ice pack. The compact ice edge ran from the south-southeast to north-northwest in direction. Swells were observed moving toward the ice edge

from the southeast. The Delft wave buoy was deployed approximately 500 meters east of the ice edge in open water. The measured spectra (Fig. 4) indicates a swell dominant seaway with a peak at 0.094 Hz.

Delft wave measurement number 03 (Fig. 5) occurred at 1350Z 22 March 1987. Northeasterly winds of 10 to 20 knots from the previously mentioned low pressure system continued to apply pressure to the ice pack. Measured ice thicknesses taken in this area varied between 0.6 and 1.6 meters. The compact ice edge at this location ran approximately west to east with 9/10 ice concentration observed in the ice pack. The Delft wave buoy was launched in open water approximately 500 meters directly south of the ice edge. Two meter swells were observed moving from the ice pack to open water in a southerly direction. The measured spectra (Fig. 5) indicates a swell dominant seaway with a peak of 0.109 Hz.

Delft wave measurement number 04 (Fig. 6) and 05 (Fig. 7) occurred on 23 March 1987 at 1455Z and 1530Z, respectively. Wind speed decreased to 5 knots at 1500Z as wind direction changed from north to northeast. Measured ice thicknesses taken at this location ranged between 1 and 2.5 meters on the larger floes. The compact ice edge at this location ran approximately from north to south with 10/10 ice concentration observed in the ice pack. Buoy measurement number 04 was taken in open water approximately 3000 meters east of the ice edge. Buoy measurement 05 was made in open water approximately 600 meters east of the ice edge. The measured spectra in Figs. 6 and 7 indicate a swell dominated seaway with peak energy located in the vicinity of 0.1 Hz.

COMPARISON WITH GSOWM

Little agreement was found between GSOWM spectral predictions and Delft wave buoy measurements for all five measurements taken in the Labrador Sea marginal ice zone, see Figs. 3 through 7. In all cases the magnitudes of GSOWM predictions for

significant wave height and peak spectral density were outside the 95 percent confidence limits of the measured data. No peak frequency agreement between the wave buoy measurement and GSOWM is displayed in Figs. 3 through 7. Measured peak frequencies consistently ranged in values between 0.094 and 0.125 Hz. GSOWM peak frequencies did not vary between measurements and were constantly higher with a value of 0.208 Hz.

SUMMARY AND CONCLUSIONS

Five wave measurements were made in the vicinity of a well-defined ice edge off the east coast of Newfoundland, Canada in March 1987. Wave measurements indicated a swell dominant seaway with significant wave heights ranging between 2.3 and 2.5 meters and modal period varying between 8.0 and 10.7 seconds. These measurements were in very good agreement with visual observations taken during the buoy deployments. Further sea trials should be conducted at the ice edge to expand the volume of environmental wave data gathered in the marginal ice zone. This data can be used to predict seakeeping characteristics of ships which may operate in the vicinity of the ice edge.

Wave measurements made during LIMEX '87 should also be correlated with open ocean wave data gathered simultaneously during the Labrador Extreme Waves Experiment (LEWEX) which took place in the Labrador Sea from 9 to 27 March 1987. Correlation of this wave data with marginal ice zone measurements may provide further insight into interaction between waves and ice.

ICE EDGES

INTRODUCTION

Sea ice data messages were provided by the Naval Polar Oceanography Center in Suitland, Maryland from 20 to 27 March 1987. Ice data messages contained latitude

and longitude number pairs which were plotted and connected with a line to produce the forecasted sea ice edge. The sea ice edge was defined as the limit of 1/10 or greater concentration of ice.[7] Labrador Sea ice edge observations were compiled and compared with the sea ice edge forecasts.

APPROACH

Sea ice data messages were plotted as shown in Figs. 8 and 9. Visual observations of the ice conditions were recorded using a state of the art NAVSAT navigation system. NAVSAT fixes were of excellent quality and occurred at frequent intervals due to the favorable latitude of the operating area (45 to 48 degrees North). NAVSAT fix accuracy was judged to be within one nautical mile of actual position. Ice edge observations were of exceptionally high quality due to the compact nature of the ice pack during LIMEX. In each case, the ice edge was very well defined and easy to identify. Observed ice edges are summarized in Table 3.

RESULTS

Sea ice data messages were received from the Naval Polar Oceanography Center on 20, 24, and 27 March 1987. Specific comparisons were made between these forecasts and observed ice conditions. In the interest of fairness, comparisons were made only during instances when the observation occurred on the same day of the ice forecasts. This resulted in only two objective comparisons. The 20 March 1987 forecast appeared to be very accurate for data supplied by both CSS BAFFIN and the Canadian oil tanker IRVING NORDIC. The 24 March 1987 sea ice data message appeared to be in excess of 30 nautical miles in error. Comparisons are summarized in Table 4.

DISCUSSION

Little information can be drawn from only two comparisons. The receipt of sea ice data messages by ships operating in the vicinity of the ice edge at intervals

of every three to four days appears to be inadequate. Daily movement of the ice edge can be significant and may have potential impact on scheduled operations (see Reference 7). As a result it is recommended that sea ice data forecasts be supplied to Navy ships on a daily basis to facilitate the planning of daily operations.

OPERATIONS IN THE ICE

INTRODUCTION

Sea ice presents a special hazard to the open ocean mariner. The uncertainty as to the exact location and concentration of sea ice coupled with the dynamic and complex nature of the ice owing to storms, currents, winds, and tides creates a danger to unreinforced vessels operating in floating ice regions. Interviews were conducted with CAPT N.St.C. Norton, master of CSS BAFFIN who had considerable ice operations experience with the Royal Navy. Appropriate observations are presented in the following paragraphs.

OBSERVATIONS

The presence of sea ice adds a special dimension to ship handling. Experienced mariners are aware of the dangers of heavy seas, shoal water, and marine traffic to ship survivability. Floating ice, however, represents a unique danger, especially to ships with hulls which are not strengthened for ice operations. References 8 through 10 provide excellent general guidance for ship-handling in ice regions along with appropriate pre-deployment preparations for operations in arctic regions.

CSS BAFFIN, an ice reinforced Canadian Fisheries vessel, spent 12 days during LIMEX operating off the coast of Newfoundland both inside and outside a compact ice pack of first year ice. Approximate ice thicknesses varied between 0.5 and 2.5 meters. One ice observer was provided by the Arctic Environmental Service of

Canada. Weather and facsimile transmissions of ice edge forecasts were provided by local sources in Newfoundland.

The success of LIMEX was significantly aided by the effective use of all available environmental information and the presence of an experienced ice observer. Despite careful preparations, approximately three days of underway time were lost during the two occasions when the ship was beset in the ice. This demonstrates the requirement to closely monitor the ice pack and the surrounding environment. The movement of the sea ice is governed by a number of factors. During LIMEX, the wind appeared to have the most influence. Wind blowing against the ice edge had the tendency to compact the ice and increase the pressure between the floes. A sudden change in wind direction can explain the reason why a ship can be safely passing through an ice field and suddenly find itself beset due to an increase in ice concentration and an increase in pressure between the ice floes. Sudden changes in the ice pack often occur after changes in wind direction and wind speed.

Other ice shiphandling lessons provided by the Master of CSS BAFFIN included:

a. Ships following an icebreaker should follow in a single column formation maintaining a distance between 500 and 2000 meters between each vessel. The following distance between the vessels should be governed by the pressure present in the ice field. High pressure between the floes in the ice field may cause the floes to quickly cover the broken ice path provided by the icebreaker. The more compact the ice, the closer it is necessary for a ship to follow an icebreaker. The following distances between each respective ship should be maximized to allow sufficient room for each trailing ship to stop in the interest of collision avoidance. An icebreaker may suddenly stop while breaking ice when it runs into a heavy ice floe. Bridge to bridge radios should be used to maintain contact with the icebreaker and adjacent ships in the column. This provides the fastest means

to identify the instant when the icebreaker stops. If the ship ahead stops, a backing bell at full speed should be ordered to stop the ship as quickly as possible.

b. Facsimile transmissions of ice forecasts provided by local sources provide good general guidance with respect to the latest status of the ice. Visual observations may be very effective during nights having a full moon and clear visibility. Lookouts should be alert for the appearance of shadows since they may be the shadows of icebergs. Close attention should be paid to the surface radar for the presence of icebergs, open leads, and ice ridges.

c. Entry into an ice field should only be attempted after careful consideration. Ice characteristics such as thickness, type, and concentration must be taken into account. Hull thickness and hull appendages are also prime considerations. Typical forms of damage to a vessel by ice include:

- Breaking or bending of propeller blades, rudder head, and rudder.
- Damage to steering gear.
- Damage to the stem and hull plating causing leaks in the forward compartments of the vessel.
- Crushing of the hull, breaking of frames due to ice pressure.[10]

d. If it is necessary for a ship to enter an ice field, the ship should enter the field at an angle which is perpendicular to the ice edge. This ensures that one of the strongest parts of the ship, the bow, enters the ice field first. Entry should be attempted at speeds slow enough to minimize the effects of ice impacts, but fast enough to maintain steerage. For a typical ship this speed will be approximately four to five knots. Floating ice fragments can be expected to increase in size as one approaches the ice pack. Ice bands are generally perpendicular to the prevailing wind direction.

e. Ships should stay clear of icebergs and give them extra "sea room" when passing. This is because approximately seven to nine tenths of an iceberg remains submerged and out of the field of view. The submerged portion of an iceberg may extend a considerable distance from the area which is exposed. Should an iceberg appear before a ship can avoid a collision, it is probably better to back the engines at maximum possible speed to reduce the impact of the collision and allow the bow to take the blow. This is usually more advantageous than turning the ship and exposing one side to damage from shelves of ice which are often projected underwater from an iceberg.[9]

DISTRESS CALLS FROM THE ICE

The hazards of operating in a constantly changing floating ice region was clearly illustrated during LIMEX on 20 March 1987 by a near disaster at sea aboard the 11,500 tonne Canadian oil tanker IRVING NORDIC. Distress calls began at 2230Z reported that IRVING NORDIC had lost propulsion while maneuvering in the ice pack in the vicinity of Saint John's, Newfoundland. During a Mayday distress call, IRVING NORDIC reported that she was on a heading of 121° T and was in danger of being run aground by sea ice which was forcing her toward shoal water to the west. Shoal water nearest IRVING NORDIC was located approximately 1.3 nmi west of her 2230Z position:

Latitude: 47°39.2'N

Longitude: 052°38.5'W

(See Fig. 8).

At 2230Z, CSS BAFFIN was an estimated 29 miles to the southeast of IRVING NORDIC, and several miles inside the ice edge due to scientific work performed earlier that day. The ice in the vicinity of CSS BAFFIN consisted of first year ice of 9 to 10 tenths concentration with small floes having thicknesses which

varied between 0.5 m and 2.5 m. At some unknown instant between the evening of 19 March and the early morning of 20 March, the wind direction changed from southwesterly to easterly with a wind speed of 20 knots. This wind change exerted pressure on the ice pack in a westerly direction and served to compress the ice field. CSS BAFFIN's rescue strategy was to rendezvous with IRVING NORDIC by exiting the ice pack to the east, and moving north in the open ocean prior to reentering the ice at a point closer to the endangered vessel.

The Canadian Coast Guard Icebreaker CCGS SIR JOHN FRANKLIN at 2230Z was approximately 24 nmi to the northeast of IRVING NORDIC and in radio contact. CCGS SIR JOHN FRANKLIN gave an estimated arrival time to IRVING NORDIC of 4 hours.

IRVING NORDIC was in severe distress at 2310Z. She regained propulsion capabilities and was running her engines at maximum speed against an ice pack which continued to push her to the west. The situation seemed hopeless. Despite all efforts, the ice pack had pushed IRVING NORDIC within 600 meters of shoal water.

CSS BAFFIN's rescue attempt failed because BAFFIN was beset in the ice and could not move from her location until the pressure inside the ice pack abated. Due to heavy ice conditions, CCGS SIR JOHN FRANKLIN did not rendezvous with IRVING NORDIC until the morning of 21 March at approximately 0930Z.

IRVING NORDIC survived this dreadful situation due to an extreme amount of luck. As the ice forced IRVING NORDIC toward the coast, portions of the ice pack ran aground piling up the ice to a point where the ice pack could no longer force the ship to the west. The ice stopped moving IRVING NORDIC when she was only 400 yards from running aground.

LESSONS LEARNED

Ship operations in ice regions require a great deal of preparation, skill, and respect for the environment. An approach to the ice pack must be made with a great

deal of caution, especially in the case of ships which have not been ice strengthened. Characteristics of an ice pack are constantly changing due to many factors, including the weather. The key to successful operations in these areas lies with the maximum use of all available assets, including local forecasts, ice observers, and helicopter reconnaissance, to determine the present status of the ice and forecast changes. Entry into high concentrations of ice by typical unreinforced ships should be highly discouraged due to the severe risks of ice damage. Becoming beset or trapped in the ice at the very least places a ship in a situation where it must wait for a relief in the ice pressure before it can escape. If the situation becomes worse, the pressure in the ice pack may increase and cause physical damage to a ship's hull and appendages. As was seen in the case of the IRVING NORDIC, the ice pack may also run a ship aground.

CONCLUSIONS

Successful operations in cold weather regions will depend on a number of factors including preparation, training, and the ability to cope with adverse environmental conditions. This report briefly discussed two environmental considerations which may significantly impact scheduled events. These factors are sea conditions and ice edge location. Prediction tools for these conditions were compared with several in situ measurements. The in situ measurements did not always agree with the predictions. Many more measurements would be required to validate GSOWM or ice edge forecasts for accuracy in a statistical sense.

Weather conditions in the MIZ are very dynamic. The location of the ice edge and specific characteristics of floating ice present in an operating area will be of particular interest to naval vessels which are not designed to operate in heavy ice regions. Development of prediction products which provide real time

environmental information to naval forces operating in northern latitude regions is highly recommended.

ACKNOWLEDGMENTS

The kind cooperation of the Bedford Institute of Technology and the CSS BAFFIN, under the able leadership of CAPT N.St.C. Norton, allowed this sea trial to be carried out. The coordination of research efforts by Ms. S.L. Bales of DTRC and Ms. S. Argus of Canada's RADARSAT Project Office is greatly appreciated. Special thanks is extended to Mr. Larry Solar of Canada's Atmospheric Environmental Service who provided excellent ice observations throughout this sea trial. Mr. R. Bachman and Mr. E. Foley of DTRC deserve special recognition for their timeless efforts and guidance.

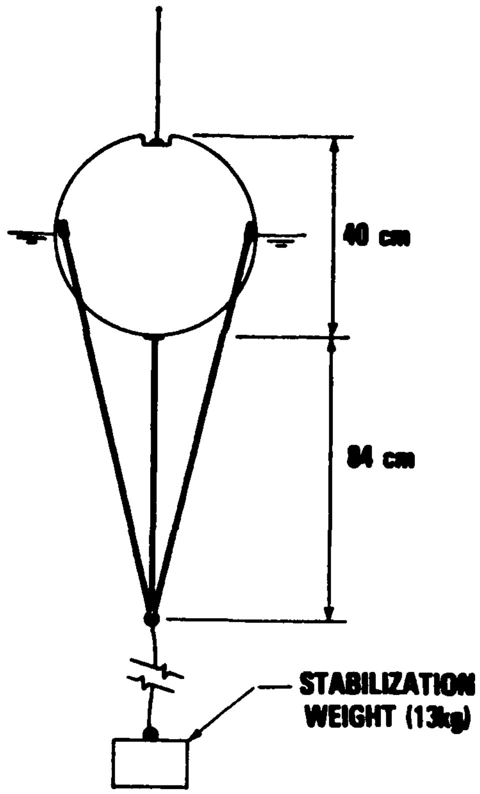


Figure 1 - Delft Disposable Wave Buoy
(Figure 2 of reference 3)

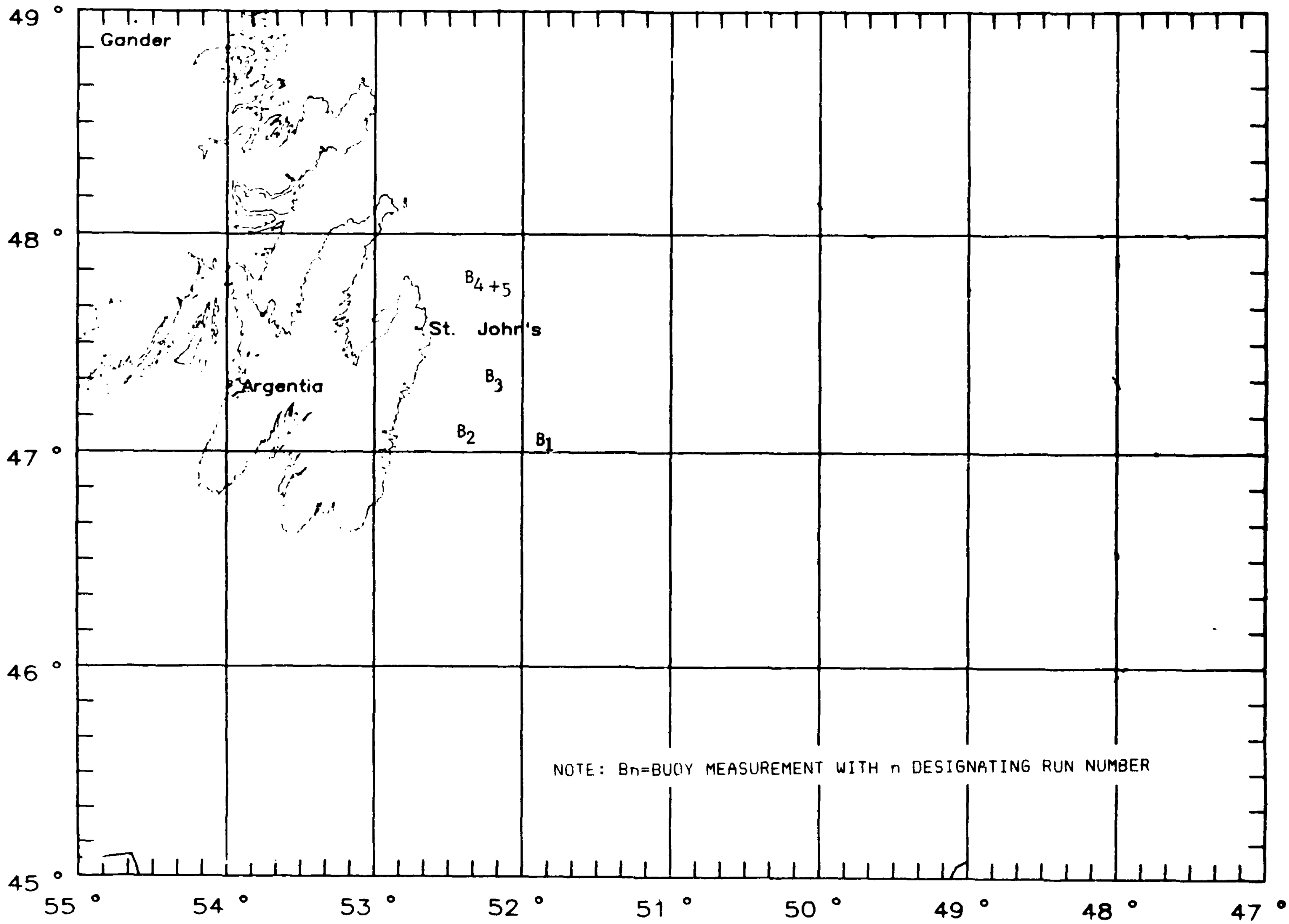
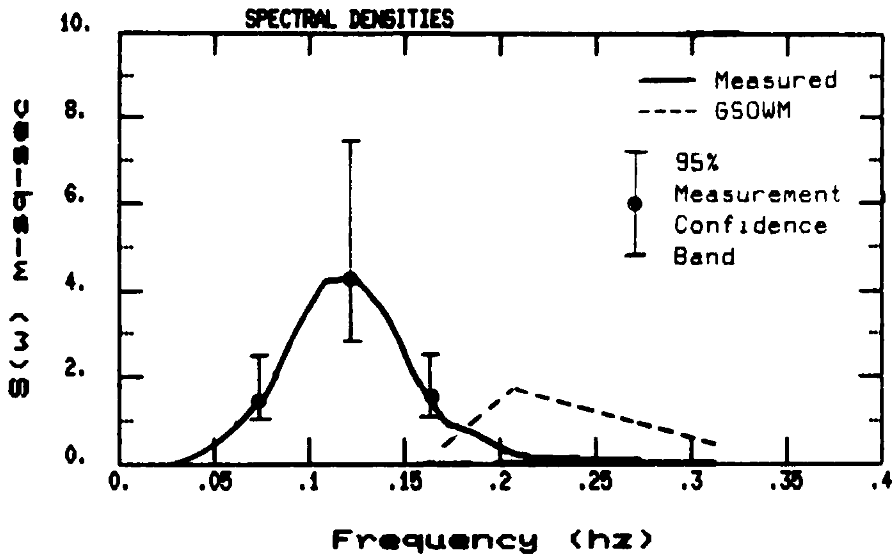


Figure 2 - Delft Wave Buoy Measurement Locations.

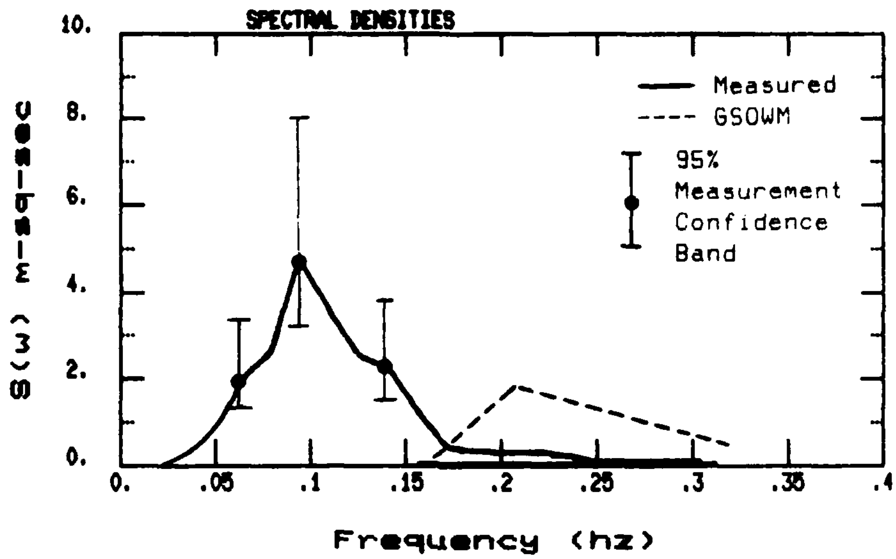


Significant Wave Height:

Delft Buoy:	2.4m	(+.7/-.5 m)*
GSOWM:	1.7m	

*95% Confidence band.

Figure 3 - Comparision between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #1.

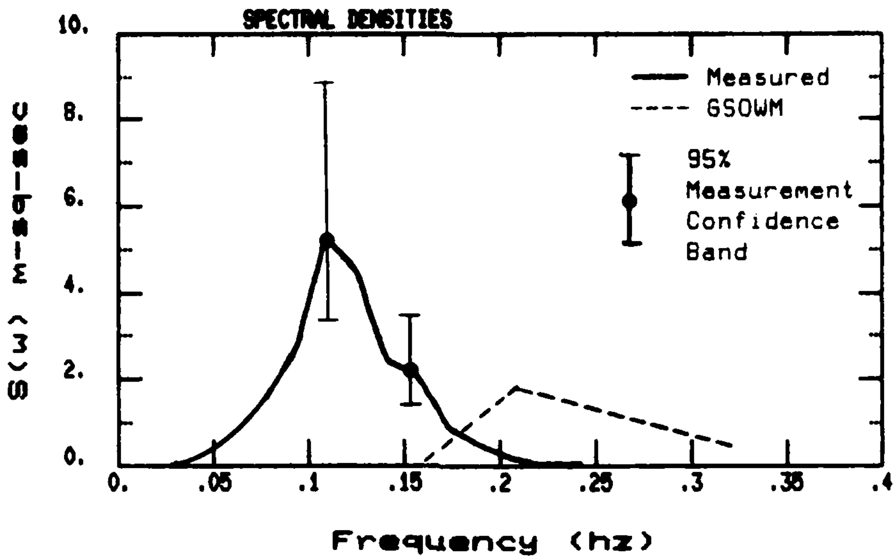


Significant Wave Height:

Delft Buoy:	2.4m	(+.7/-.5 m)*
GSOWM:	1.7m	

*95% Confidence band.

Figure 4 - Comparision between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #2.

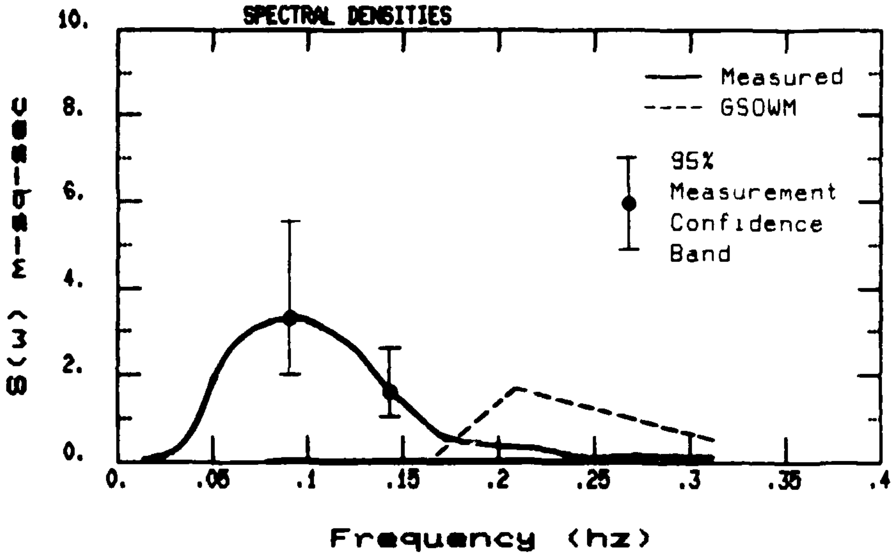


Significant Wave Height:

Delft Buoy:	2.3m	(+.7/-.4m)*
GSOWM:	1.7m	

*95% Confidence band.

Figure 5 - Comparision between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #3.

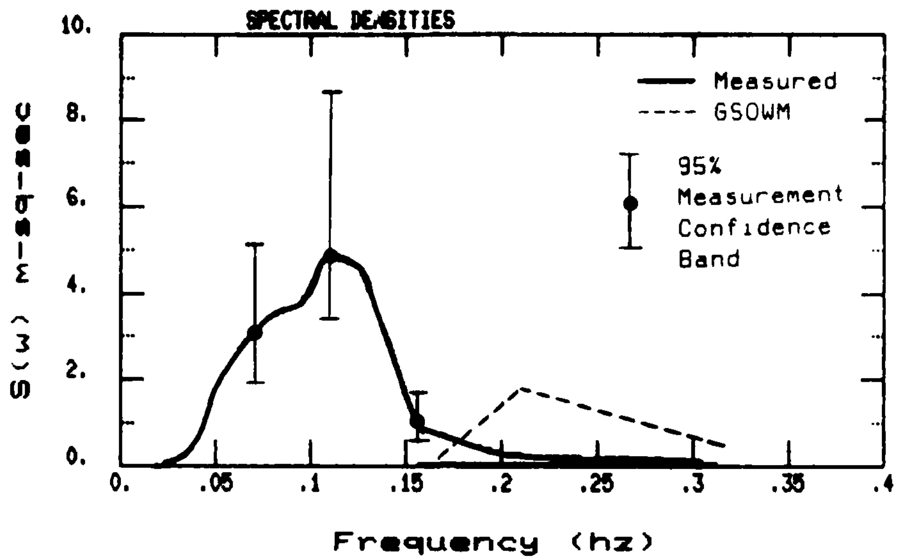


Significant Wave Height:

Delft Buoy:	2.4m	(+.7/-.5m)*
GSOWM:	1.7m	

*95% Confidence band.

Figure 6 - Comparision between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #4.



Significant Wave Height:

Delft Buoy:	2.5m	(+.8/-.5m)*
GSOWM:	1.7m	

*95% Confidence band.

Figure 7 - Comparision between GSOWM wave spectra and wave buoy measured spectra for Buoy Measurement #5.

LIMEX ICE EDGE DATE: 20 MARCH 1987

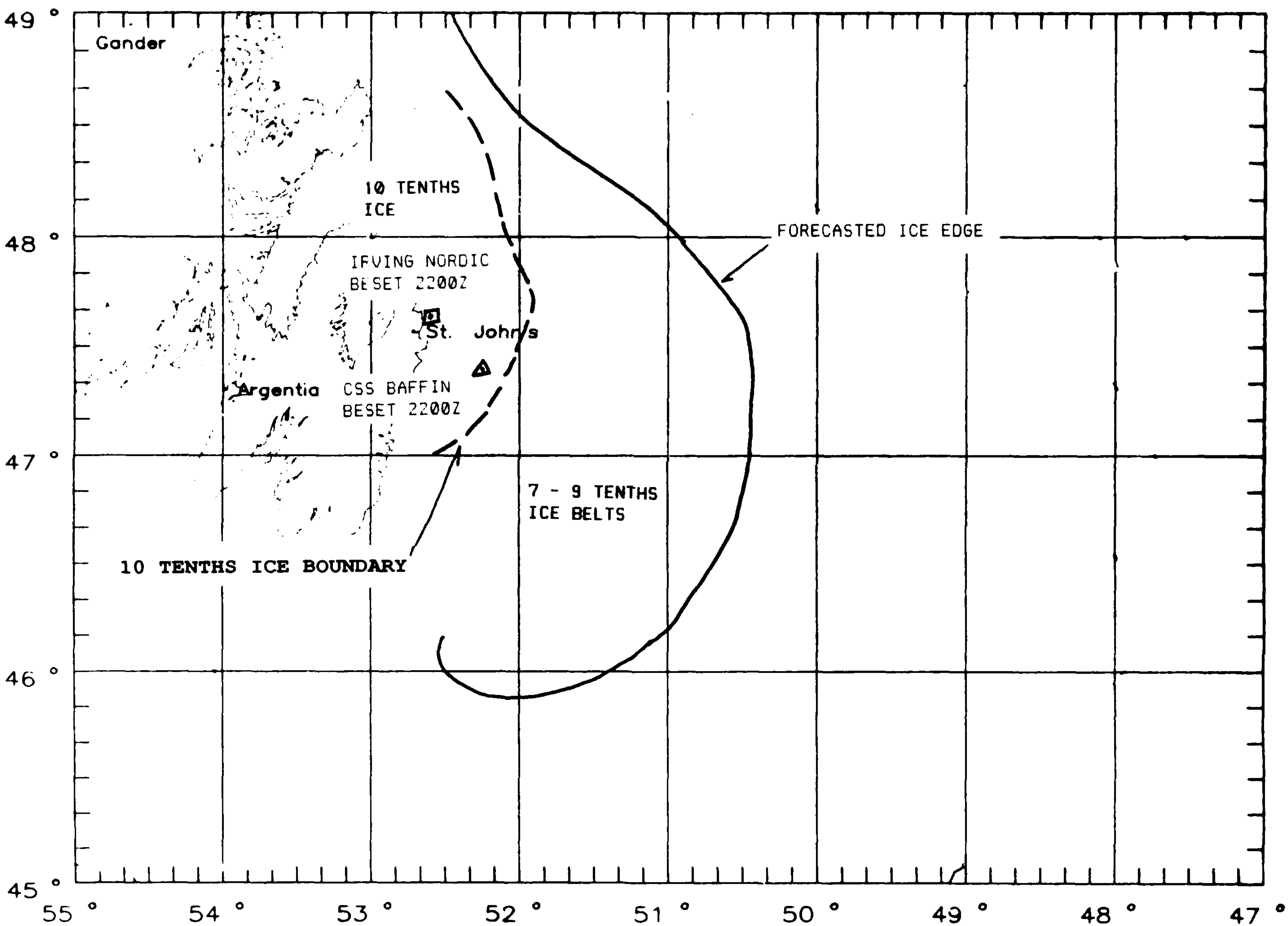


Figure 8 - CSS Baffin and Irving Nordic beset positions compared with Sea Ice Data Message Forecast.

LIMEX ICE EDGE   DATE: 24 MARCH 1987

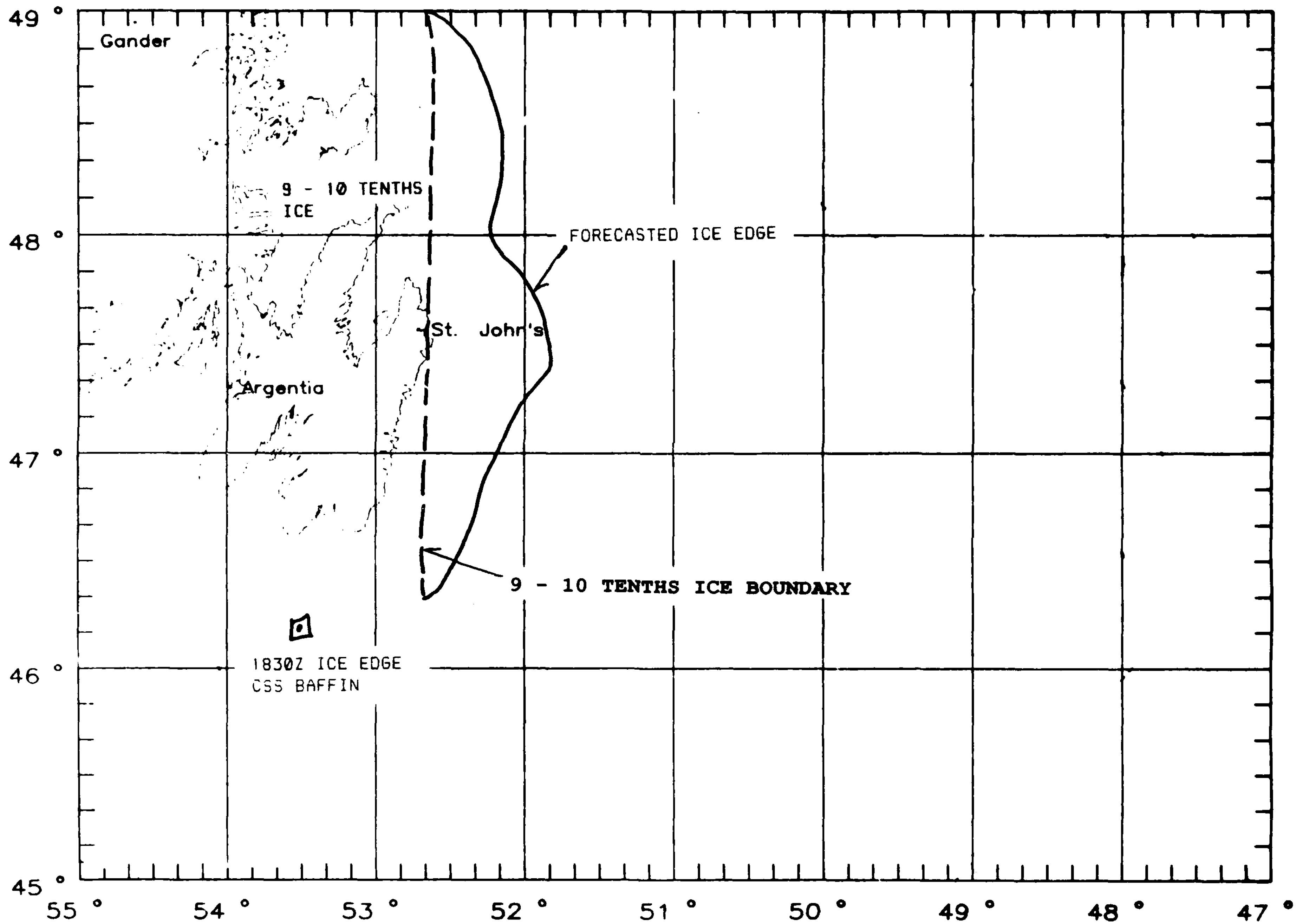


Figure 9 - CSS Baffin observed ice edge location compared with Sea Ice Data Message Forecast.

Table 1. Delft wave buoy characteristics (from Reference 4).

Working lifetime	8 hours
Transmitted power	1.5 watts
Transmitted frequency	27.7 MHz
Buoy diameter	0.43 m
Length of antenna	1.5 m
Mass of buoy	10.2 kg
Mass of stabilization weight	10.2 kg
Max ship speed during deployment	24 knots
Wave data provided after analysis	Nondirectional point spectra

Table 2. Delft wave buoy measurements taken aboard CSS BAFFIN in the Labrador Sea in March 1987.

Buoy Measurement	Launch Position	Launch Time	Distance to Ice Edge	Ice Concentration	Ice Thickness
1	Lat: 47.05N Long:051.92W	1700Z 19 Mar	500 m*	8/10	0.3-2.5 m
2	Lat: 47.10N Long:052.44W	1655Z 21 Mar	500 m	10/10	0.3-2.5 m
3	Lat: 47.34N Long:052.26W	1350Z 22 Mar	500 m	9/10	0.6-1.6 m
4	Lat: 47.83N Long:052.38W	1455Z 23 Mar	3000 m	10/10	1 - 2.5 m
5	Lat: 47.83N Long:052.38W	1530Z 23 Mar	600 m	10/10	1 - 2.5 m

* This wave measurement was taken in an open lead 500 m inside the ice pack. All other measurements were made outside of the ice pack in open water.

Table 3. Labrador Sea March 1987 LIMEX ice edge observations.

Date (1987)	Time (Z)	Latitude (N)	Longitude (W)
17 March	2350	46°30.98'	53°21.64'
19 March	1630	47°03.39'	51°54.93'
21 March	1810	47°06.50'	52°28.89'
22 March	1350	47°20.55'	52°15.44'
23 March	1300	47°47.69'	52°26.83'
24 March	1830	46°11.90'	53°30.38'
25 March	1650	46°25.81'	53°00.75'
25 March	2140	46°23.85'	53°04.81'
26 March	1205	47°00.66'	52°44.79'

Table 4. Comparison of observed ice conditions with sea ice data messages during March 1987 LIMEX experiment.

Date (1987)	Time (Z)	Comparison Remarks
20 March	2200	In agreement with sea ice data message.
24 March	1830	Observed ice edge falls at least 30 nmi southwest of forecasted ice edge.

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